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QCD CORRECTIONS TO $b\bar{b}/c\bar{c}$ PAIR PRODUCTION IN POLARIZED $\gamma\gamma$ COLLISIONS AND THE INTERMEDIATE MASS HIGGS SIGNAL¹

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Abstract

We present production rates of the two- and three-jet final states for the processes of massive $c\bar{c}/b\bar{b}$ quark production in circularly polarized photon-photon collisions, including QCD radiative corrections. Lowest order cross section, one-loop virtual correction and gluon emission correction are shown to be of the same order of magnitude for $b\bar{b}$ quark production at $\sqrt{s_{\gamma\gamma}} \sim 100$ GeV. It is shown that the signal from intermediate mass Higgs boson is observable at photon-photon collider, although the statistical significance is substantially reduced with respect to the tree level calculation.

A very exciting potential application of photon-photon collisions at a 100-200 GeV linear collider is the intermediate mass Higgs boson production in photon fusion reaction [1-5]

$$\gamma\gamma \rightarrow H \rightarrow b\bar{b}.$$

In addition, new interesting method was proposed [6, 7] to measure the parity of the Higgs states in linearly polarized photon-photon collisions. It provides an opportunity to investigate non-trivial assignment of the quantum numbers for Higgs particles in extended models such as supersymmetric theories which include both scalar 0^{++} and pseudoscalar 0^{-+} states [8].

Extracting the intermediate mass Higgs signal in photon-photon collisions is a hard task since large number of $b\bar{b}/c\bar{c}$ background events must be rejected [1, 2, 9]. The crucial assumption is that these large backgrounds can be actively suppressed by exploiting the polarization dependence of the cross sections. Far above the threshold, the $\gamma\gamma \rightarrow q\bar{q}$ cross section is dominated by initial photons in the $J_z = \pm 2$ helicity state. Taking into account that the Higgs signal comes from the $J_z = 0$ channel, polarized collisions can be used to enhance the signal while simultaneously suppressing the background [1, 2] (see also detailed discussion in these proceedings [10, 11]). But

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the question remains how do QCD radiative corrections influence these conclusions. While it is known that far above the threshold the magnitude of these corrections is moderate for unpolarized collisions [12, 13], one can expect that their effects will be especially large for $q\bar{q}$ production in $J_z = 0$ helicity state, where the tree level contribution is suppressed as m_q^2/s .

We present here the results of the one-loop calculation of the QCD corrections to $b\bar{b}/c\bar{c}$ quark pair production in polarized photon-photon collisions retaining the full dependence on the quark masses. The total cross section calculated up to the order $\alpha^2\alpha_s$ is given by the sum of tree-level $\gamma\gamma \rightarrow q\bar{q}$ contribution, the interference term between one-loop and the tree level contributions, and tree level contribution from quark pair production accompanied by gluon emission $\gamma\gamma \rightarrow q\bar{q}g$. The first two contributions lead to two parton final states converting mainly into two jets, while the third one leads to three parton production converting both into two- and three-jet final states. The reason is that three parton final states with collinear and/or soft gluon will appear experimentally as two jets. Moreover, only the sum of the cross sections of $q\bar{q}$ production and $q\bar{q}g$ with soft or collinear gluon is free from infrared divergences and has no singularities in the limit $m_q \rightarrow 0$. So, as usual, we consider the three parton state to represent two-jet final state if the invariant mass of two partons is sufficiently small

$$s_{i,j} < y_{cut}s_{\gamma\gamma},$$

where $s_{i,j} = (p_i + p_j)^2$ is the invariant mass squared of two partons i and j and $\sqrt{s_{\gamma\gamma}}$ is the total c.m.s. energy of two colliding photons.

Fig. 1 shows total (*i.e.* two-jet plus three-jet) and two-jet ($y_{cut} = 0.08$) cross sections for $b\bar{b}/c\bar{c}$ pair production in polarized monochromatic $\gamma\gamma$ collisions. While the QCD corrections for $J_z = \pm 2$ photon helicities are quite small, those for $J_z = 0$ enhance $c\bar{c}$ production by an order of magnitude or even larger. For $b\bar{b}$ production the situation is more complicated: the corrected total cross section is smaller than the tree level $\gamma\gamma \rightarrow b\bar{b}$ cross section for $\sqrt{s_{\gamma\gamma}} < 85$ GeV and larger for larger energies. The effect is more pronounced for two-jet production. For small values of $y_{cut} < 0.04$ the two-jet differential cross section is even negative in some regions of the phase space. This means that for $b\bar{b}$ production at $\sqrt{s_{\gamma\gamma}} \sim 100$ GeV all three contributions (lowest order, virtual and gluon emission) are of the same order of magnitude. This is unlike the case of $c\bar{c}$ production, where the gluon emission contribution dominates. Therefore the approach of [3, 11], where only one contribution from radiative processes $\gamma\gamma \rightarrow c\bar{c}g$, $b\bar{b}g$ is taken into account in the limit $m_c, m_b \rightarrow 0$ (for $J_z = 0$ and $m_q = 0$ the cross section is given by this only contribution), may be relevant for $c\bar{c}$ production, but is definitely not applicable for $b\bar{b}$ production.

Fig. 2 shows the events rates of signal and background two-jet final states in photon-photon collisions. We make here the same assumptions as in [2], *i.e.* we choose the broad photon-photon luminosity spectrum resulting from polarized linac and laser in the $\lambda_\gamma\lambda_e > 0$ direction, $\lambda_e = 0.9$, $\lambda_\gamma = 1$, parameter $x = 4.8$ and geometric factor $\rho = 0.6$ [2, 14]. We also assume the linac beam energy to be equal to 125 GeV

and integrated effective luminosity of 10 fb^{-1} . Such a choice is preferable when trying to cover the entire intermediate Higgs mass region. We ignore here backgrounds from $e\gamma \rightarrow eZ \rightarrow e b\bar{b}$ and $\gamma\gamma \rightarrow f\bar{f}Z$ processes [16], which are essential for $m_H \sim m_Z$. The backgrounds coming from the resolved photon contributions $\gamma g \rightarrow b\bar{b}$, $c\bar{c}$ are also shown. While resolved photon contributions make almost impossible to observe the intermediate mass Higgs signal at 500 GeV linear collider [9], these backgrounds are much less significant at 250 GeV due to a steeply falling gluon spectrum (see also [2, 7]). QCD corrections to Higgs decay into $b\bar{b}$ [15] are also taken into account. We use a cut of $|\cos\theta| < 0.7$ in the laboratory frame and not in c.m. frame as in [2]. Cut in the laboratory frame gives slightly better statistical significance of the Higgs signal. Finally, we assume 5% $c\bar{c}$ -to- $b\bar{b}$ misidentification probability. Thus, the combined background (*i.e.* $b\bar{b} + 0.05c\bar{c}$) is represented by dotted line and can be compared with the signal denoted by solid line.

Fig. 3 presents the statistical significance of the Higgs boson signal estimated from tree level as well as one-loop calculations including the resolved photon contributions. This plot assumes 90% $b\bar{b}$ -tagging efficiency for the $b\bar{b}$ final states and the resolution for reconstructing the invariant mass of a two-jet events to be Gaussian with $FWHM = 0.1m_H$. From this figure one can conclude that it is advantageous to select two-jet final states and to impose the angular cut in the laboratory frame. The account of QCD corrections reduces the statistical significance of Higgs signal almost by a factor of two in comparison to tree-level result. Nevertheless the intermediate mass Higgs boson can be observed in $\gamma\gamma$ collisions at least at the level of 5σ in the mass interval from 80 to 160 GeV. Our estimates here should be considered as a first-order determination of the influence of QCD radiative corrections on the statistical error in the measurement of the two-photon Higgs width. A more detailed analyses including full detector simulation is certainly needed.

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Figure captions

Fig. 1. Cross sections for $\gamma\gamma \rightarrow c\bar{c}$ and $\gamma\gamma \rightarrow b\bar{b}$ for polarized monochromatic photon beams, $++$, $+-$ correspond to $J_z = 0$ and $J_z = \pm 2$, respectively. Solid (dashed) line is tree level (one-loop corrected) cross section for $b\bar{b}$ production. Dotted (dash-dotted) line is tree level (one-loop corrected) cross section for $c\bar{c}$ production. First figure gives total cross section. The second is two-jet production cross section.

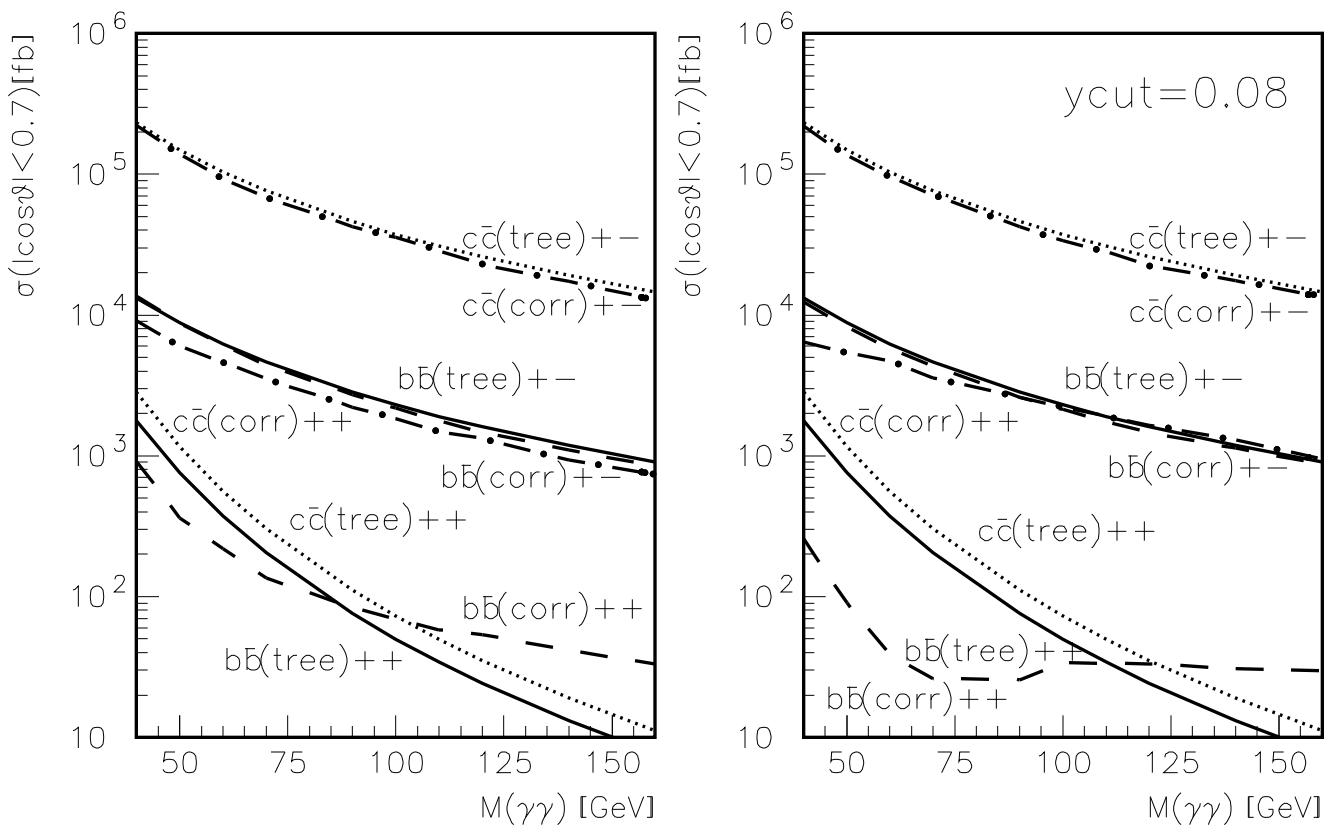
Fig. 2. Expected event rates for the Higgs signal and background processes. Two-jet final states are considered. Lowest order as well as one-loop corrected results are shown.

Fig. 3. Statistical significance of the intermediate mass Higgs boson signal. Solid line corresponds to two-jet final states with the angular cut in the laboratory frame. Dashed curves correspond to cut in c.m.s. of colliding photons. “All” represents the sum of two- and three-jet final states. Dash-dotted curves represent the results of the lowest order calculation and the effect of the account of resolved photon contribution.

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Figure 1. G. Jikia and A. Tkabladze



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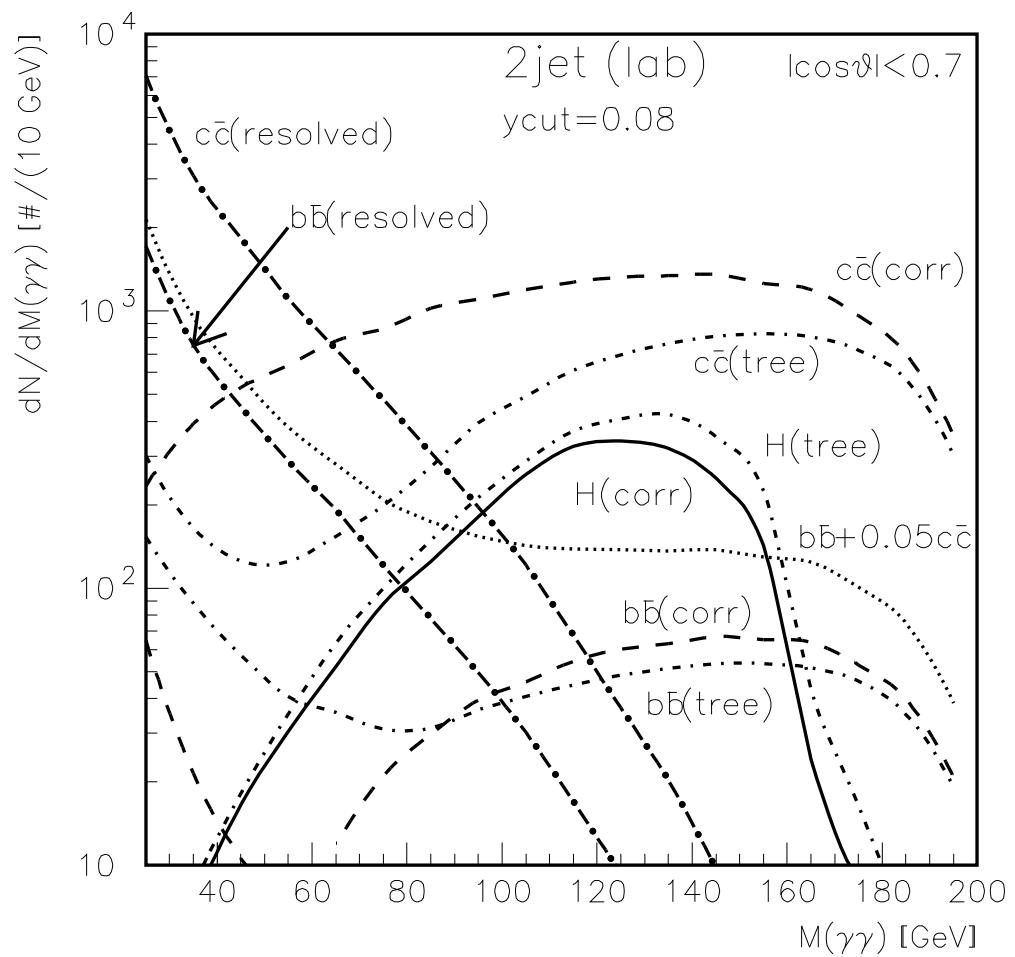


Figure 2. G. Jikia and A. Tkabladze

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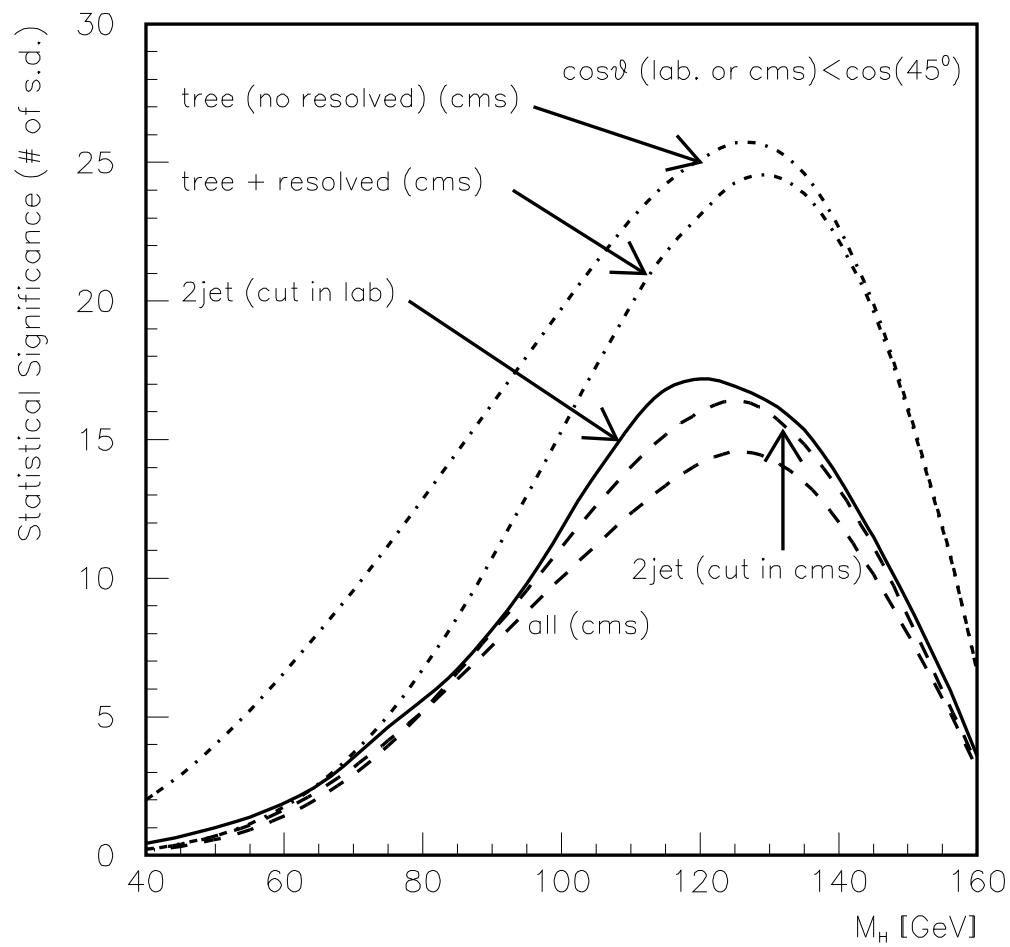


Figure 3. G. Jikia and A. Tkabladze